Thermographic super resolution reconstruction using 2D pseudo-random pattern illumination

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Thermographic non-destructive testing is based on the interaction of thermal waves with inhomogeneities. The propagation of thermal waves from the heat source to the inhomogeneity and to the detection surface according to the thermal diffusion equation leads to the fact that two closely spaced defects can be incorrectly detected as one defect in the measured thermogram. In order to break this spatial resolution limit (super resolution), the combination of spatially structured heating and numerical methods of compressed sensing can be used.

The improvement of the spatial resolution for defect detection then depends in the classical sense directly on the number of measurements. Current practical implementations of this super resolution detection still suffer from long measurement times, since not only the achievable resolution depends on performing multiple measurements, but due to the use of single spot laser sources or laser arrays with low pixel count, also the scanning process itself is quite slow. With the application of most recent high-power digital micromirror device (DMD) based laser projector technology this issue can now be overcome.

In this work we share our progress on improving the defect/inhomogeneity characterization using fully 2D spatially structured illumination patterns instead of scanning with a single laser spot. The experimental approach is based on the repeated blind pseudo-random illumination using modern projector technology and a high-power laser (see Fig. 1).

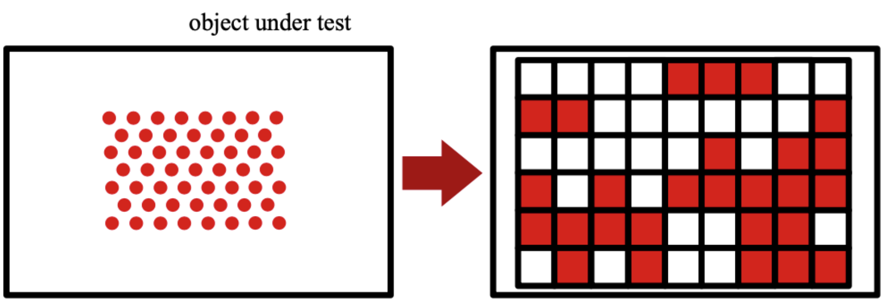

Fig. 1. Point-wise heating pattern with single laser spots; each spot is illuminated one after another to guarantee independent measurements (Left); pixelated pseudo-random pattern illuminated as a whole; multiple of those patterns are used for the subsequent defect reconstruction (Right).

In the subsequent super resolution based defect reconstruction several measurements are combined by taking advantage of the joint sparsity of the defects within the sample. Here, enhanced nonlinear convex optimization techniques are utilized for solving the underlying ill-determined inverse problem for typical simple defect geometries. As a result, a higher resolution defect/inhomogeneity map can be obtained at a fraction of the measurement time previously needed.